INTERSEGMENTAL COORDINATION: AN EXPLORATION OF CONTEXT

M. Bird, L. Hills, and J. L. Hudson
University of North Carolina at Greensboro, NC USA

Intersegmental coordination in complex, forceful movements has been discussed in the biomechanics teaching literature for many years. Until recently the presumption has been that the optimal pattern of coordination was sequentially timed (Morehouse & Cooper, 1950; Bunn, 1972). That is, the sequencing of segments was ordered from proximal to distal, and the timing of segments was arranged such that exactly one segment contributed positively to the movement at a given time. Deviations from optimal timing were described by Morehouse and Cooper in continuous terms ranging from "early" (i.e., overlaps in segmental contribution) to "late" (i.e., gaps in segmental contribution). Similarly. Bunn (1972) advised against "simultaneous" or "jerky" movements.

In 1981 Kreighbaum and Barthels suggested a different timing continuum with polar positions of simultaneous (i.e., all segments contribute concurrently) and sequential (i.e., each segment contributes serially). Also, they postulated that the position on the continuum for a particular performer and (ask would be related to contextual factors. For example, if the performer were a beginner or the task involved rectilinear movement, limited incorporation of segments, lever-like movement, or accuracy, the expected mode of timing would be simultaneous. If the performer were advanced and the task involved curvilinear movement, maximal incorporation of segments, wheel-axle movement, or velocity, the expected mode of timing would be sequential. Given the complexity of sports skills in terms of these contextual factors, it is not surprising that there are few empirical studies of context and coordination. Therefore, the purpose of this study was to explore the intersegmental coordination of beginning and advanced performers in a two-segment, lever-like task with velocity and accuracy demands.

METHODOLOGY

The (ask for this study was the badminton deep serve. This underhand movement requires sufficient accuracy to place the shuttlecock in the rear section of the opponent's court and sufficient velocity to enable the shuttlecock to travel high as well as far. In addition, the propulsive phase of this skill is relatively planar. Given the similarities between striking a shuttlecock and a golf ball, Milburn's (1982) two-segment model was employed in this investigation. This model consists of the arm rotating at the shoulder and the racquet rotating at the wrist

The subjects for this study were five right-handed adults with **different backgrounds** in badminton. One subject was an advanced player with college varsity experience. and **four** subjects were beginning players with six **weeks of** instruction. Each subject performed ten deep serves which were videotaped *from* the right side using a **Panasonic** video camera engaging a **1 / 1 0** second high-speed shutter. **Based** on height **and** depth with respect to vertical and horizontal markers in the opponent's court **(Verducci, 1980). the** best **trial** for each subject was selected for analysis. Reflective *tape* on the shoulder. elbow, wrist, hip, and racket was digitized with a **PEAK** Performance **2D** Motion Measurement System. After the raw **data** were **smoothed at** 6 Hz using a low-pass, fourth order. zero lag **Butterworth** digital filter, shoulder and wrist angular velocities were computed to **determine** the pattern of **coordination.** The propulsive phase for each segment was defined as beginning when the joint velocity crossed the zero velocity line (or when a radical upward slope in the velocity **occurred)** and ending when the joint velocity reached maximum. Sequencing was denoted by the order in which segments **initiated** and terminated propulsion. Timing was **assessed** by shared positive contribution (Hudson. **1986).** That is, the time **that** both segments were in propulsion was divided by the time that either segment was in propulsion.

RESULTS AND DISCUSSION

All subjects were able to hit at least one high serve to the rear of the opponent's badminton court. As expected, the primary contributions **to** propulsion *appeared* to come from shoulder and wrist flexion. The **head of** the racket **moved in a curvilinear path** and achieved a linear velocity at contact of about 24 **m/s.** in general, the serve was planar and lever-like, but the advanced player may have **attained** some racket velocity from wheel-axle movements because the apparent length of the racket was slightly shortened during the 0.03 **s** interval surrounding contact The graphs in Figure 1 contain the the angular velocities vs. **time** for the shoulder and **wrist** of each subject.

The advanced player **(A)** initiated the forward swing with shoulder flexion while the wrist was held relatively motionless in about 70° of hyperextension. The propulsive phase of the wrist began as the shoulder reached peak angular velocity and ended as the wrist reached peak angular velocity at contact. Thus, there was proximal-to-distal sequencing in both the initiation and termination of segmental contribution. As for timing. **A** had a shared positive contribution (SPC) of **0%.** That is, there was neither an overlap nor a gap between the **contributions at** the shoulder and wrist pints. In sum, the advanced player exhibited an "optimal" sequential pattern of **intersegmental** coordination.

Two of the beginning players **(B**1 and **B2)** had initial similarities to the advanced player: They began the forward swing with shoulder flexion while the wrist was held relatively motionless in about **60-80°** of hyperextension. These beginners diverged from the advanced player when they initiated propulsion at the wrist prior to terminating propulsion at the shoulder. Also. B2 differed from B1 by co-terminating propulsion at

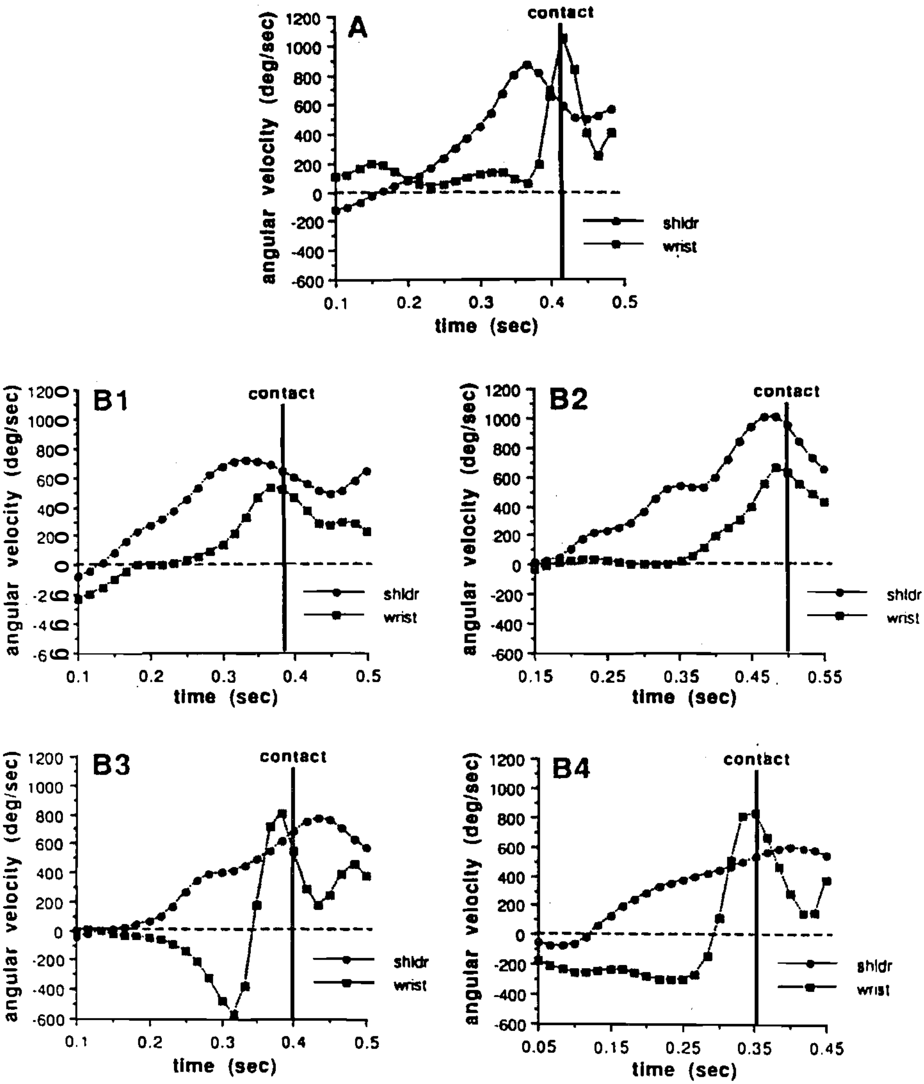

Figure 1. Angular Velocity of shoulder and wrist for advanced (A) and beginning (B) players.

the shoulder and wrist. Thus, B1 used proximal-to-distal sequencing in initiation and termination, but B2 used proximal-to-distal sequencing in initiation and simultaneous sequencing in termination of propulsion. In terms of bisegmental coordination, B1 and B2 had a SPC of about 45%. Assuming that simultaneous coordination is represented by a SPC of 100% and sequential coordination is represented by a SPC of 0%, B1 and B2 had intermediate coordination (i.e., about equidistant from both simultaneous and sequential). Given that B1 and B2 had greater velocity in the shoulder joint compared to the wrist joint, these subjects could be characterized as using a shoulder-dominant technique. It may not be coincidental that, of all subjects, B1 and B2 had the greatest upper body strength.

The other two beginning players (B3 and B4) began the forward swing with shoulder flexion while the wrist moved from moderate hyperextension (~45°) to greater hyperextension (~70°) with the use of a counter movement. At the completion of the counter movement (.06 s before contact), the wrist began flexing well before the shoulder reached peak velocity. In fact, the wrist completed propulsion and contact was made before the shoulder reached peak velocity. Thus, B3 and B4 used proximal-to-distal sequencing in initiation and distal-to-proximal sequencing in termination of propulsion. These subjects, with a SPC of 15-20%, had predominantly sequential timing. Given the high angular velocity and counter-movement strategy of the wrist, B3 and B4 could be characterized as using a wrist-dominant technique.

CONCLUSIONS

The following conclusions were drawn about beginning and advanced performers in a two-segment, lever-like task with velocity and accuracy demands: The initiation of propulsion followed a proximal-to-distal sequence for beginning and advanced players. However, successful outcomes were achieved by terminating propulsion with proximal-to-distal, simultaneous, and distal-to-proximal patterns of sequencing and by employing classically sequential, predominantly sequential, and half simultaneous-half sequential patterns of timing. The choice of sequencing and timing patterns may be dependent on individual talents (e.g., shoulder-girdle strength) or preferences (e.g., employment of counter movement). Because the beginning players who were most like the advanced player in sequencing were least like the advanced player in timing, the simultaneous-sequential continuum of coordination may not be an appropriate classification scheme for some beginners in some contexts.

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